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54 **Niedrigschmelzendes binäres Glas zur Verwendung als dielektrische Schicht in einer Vielschichtstruktur.**

57 A binary glass for use in integrated circuits has a softening or flow point far below temperatures at which glasses normally used in connection with integrated circuits flow. Preferably the glass comprises a mixture of germanium dioxide and silicon dioxide wherein the germanium dioxide is no greater than approximately 50 % by weight of the mixture. Phosphorus is added to the glass film for passivation of the underlying devices.

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1 A LOW TEMPERATURE BINARY GLASS FOR USE AS A
2 MULTILEVEL DIELECTRIC LAYER

3 William I. Lehrer
4

5 BACKGROUND OF THE INVENTION
6

7 Field of the Invention
8

9 This invention relates to a glass suitable for depo-
10 sition by chemical vapor deposition ("CVD") techniques
11 which has a softening (or "flow") point far below tempera-
12 tures at which glasses currently used in the semiconductor
13 industry flow.
14

15 Description of the Prior Art
16

17 The vapor deposition of phosphorus-doped silicon
18 oxides onto a substrate is well-known. Such glasses are
19 typically used to passivate the surfaces of integrated
20 circuits made using silicon. Commonly denoted as "PVx" or
21 "phosphorus doped vapox", glasses formed in this manner
22 have very high melting points in the range of 1000°C to
23 1100°C. To reflow these glasses to remove sharp edges and
24 provide curved, gradual-sloping surfaces on which con-
25 ductive leads can easily be formed with gradual, rather
26 than abrupt, changes in surface height, thereby to reduce
27 the likelihood of such leads cracking or breaking, the
28 integrated circuit must be heated to temperatures within
29 the range of 1000° to 1100°C. Such high temperatures
30 change the diffusion profiles of the various doped regions
31 within the integrated circuit which give to the circuit
32 its electrical characteristics. This is undesirable.
33 Thus the fabrication of a semiconductor integrated circuit,
34 particularly one using more than one level of conductive
35 leads (known as a "multilevel" structure) becomes highly
36 complicated with the final characteristics of the device
37 differing somewhat from the characteristics of the device
38

1 prior to the formation of the various levels of conductive
2 leads.
3

4 The formation of glasses suitable for use as passi-
5 vating and/or insulating layers in integrated circuits
6 which melt at temperatures significantly below the 1000°C
7 to 1100°C temperatures at which glasses currently used in
8 integrated circuits melt is particularly important now
9 that laser annealing and glass reflow techniques are
10 becoming commonly used in semiconductor processing. In
11 the past, various glass mixtures have been used or proposed
12 to achieve lower melting temperatures. Thus sedimented
13 glasses have been proposed for use in the manufacture of
14 integrated circuits with the constituents of the glasses
15 being selected such that these glasses melt at a substan-
16 tially lower temperature than the melting temperatures of
17 commonly used phosphorus-doped vapor deposited oxides of
18 silicon. Unfortunately, the techniques used to control
19 the thicknesses of the deposited glasses and the tech-
20 nologies for depositing the glasses differ substantially
21 from the techniques and technologies currently used in the
22 semiconductor industry in the vapor deposition of oxides
23 of silicon (both undoped and doped with phosphorus).
24

25 SUMMARY OF THE INVENTION

26

27 This invention substantially overcomes the above
28 problems by providing a thin glass film suitable for use
29 as insulation in semiconductor devices. The glass of this
30 invention utilizes the same equipment as utilized to form
31 the phosphorus doped vapox of the prior art but produces a
32 glass which has a melting point far below temperatures
33 which cause dopant diffusion problems.
34

35 In accordance with this invention, a binary glass is
36 deposited in a CVD (i.e., chemical vapor deposition)
37 reactor from a germane/silane ($\text{GeH}_4/\text{SiH}_4$) co-deposition
38

1 source by reacting these two gases at temperatures ranging
2 from approximately 350°C to 500°C with oxygen in a nitrogen
3 carrier gas. The resulting glass (a germanium dioxide-
4 silicon dioxide mixture) has a useful range of flow points
5 typically between approximately 700°C to 900°C thereby
6 making it particularly attractive for use as a dielectric
7 material in multilevel integrated circuit structures.
8

9 The addition of phosphorus in the form of phosphorus
10 pentoxide (P_2O_5) by blending phosphine (PH_3) into the
11 deposition gas stream at a selected percentage by weight
12 results in an excellent passivated glass film which, by
13 controlling the phosphorus level to be relatively low,
14 substantially eliminates corrosion, a common problem in
15 prior art integrated circuits using phosphorus-doped
16 passivation of glass together with aluminum interconnect
17 structures.
18

19 DETAILED DESCRIPTION OF THE INVENTION
20

21 In accordance with this invention, a mixture of
22 germanium dioxide and silicon dioxide is deposited on an
23 appropriate substrate, such as a silicon wafer used in the
24 manufacture of integrated circuits, in a conventional
25 chemical vapor deposition reactor of a type commonly known
26 and used in the semiconductor industry, from a co-deposition
27 source of germane (GeH_4) and silane (SiH_4). In a preferred
28 embodiment, the deposition is carried out by reacting
29 these two gases at temperatures ranging from 350°C to
30 500°C with oxygen in a nitrogen carrier gas. A typical
31 preferred ratio for the deposition of this glass is
32 approximately:
33

34 <u>Constituents</u>	35 <u>Flow Rates</u>
36 GeH_4	3.67 cc/min
37 SiH_4	7.33 cc/min
38	

4 where "cc" means cubic centimeters and "L" means liters.
5 The above constituents are reacted at 450°C. Of importance,
6 GeH_4 is more reactive than SiH_4 . Thus, the result of this
7 reaction is a glass film which will, undoped, in a nominal
8 50-50 mixture by weight, melt at about 850°C when placed
9 in a furnace with nitrogen at this temperature and held at
10 this temperature for 30 minutes.

12 In a variation of this process, phosphorus pentoxide
13 (P_2O_5) is introduced into the gas stream by blending
14 phosphine (PH_3) into the gas stream in an amount ranging
15 from three to nine percent (3-9%) by weight. The result-
16 ing phosphorus doped glass forms an excellent film and
17 melts between 700° to 900°C.

19 A characteristic of germanium dioxide (GeO_2) is that
20 this material exists in both soluble and relatively
21 insoluble forms in water. When germanium dioxide is grown
22 alone at normal temperatures, the resulting glass is
23 soluble in water. Germane (GeH_4) is a commercially avail-
24 able substance supplied by a number of vendors. The
25 germane used in this process is of the quality generally
26 available in the marketplace.

As the percentage of germanium dioxide in the resulting germanium dioxide/silicon dioxide glass mixture increases to above somewhere in the 45-55% range, the resulting binary mixture starts to become relatively more soluble in water than phosphorus-doped silicon dioxide. By holding the percentage by weight of germanium dioxide in the mixture less than between 45-55% by weight, the resulting binary glass film is not significantly more water soluble than phosphorus-doped silicon dioxide (that is, its solubility is on the same order as PVx). Such a

1 binary glass film is substantially insoluble in water.
2 When the percentage by weight of germanium dioxide in the
3 binary glass becomes greater than about 50%, however, the
4 oxide becomes relatively more water soluble.
5

6 The addition of phosphorus in the form of P_2O_5 in the
7 range of 3% to 9% by weight to the resulting glass lowers
8 the softening temperature of the glass to about 700°C.
9 Without phosphorus, the glass begins to soften at approxi-
10 mately 800°C.
11

12 An important feature of the binary glass of this
13 invention is that it can be deposited using standard
14 equipment currently used in the semiconductor industry for
15 the deposition of phosphorus doped oxides of silicon.
16 Thus the basic deposition technology and equipment is
17 already available for use in practicing this invention.
18

19 By increasing the phosphorus content in the binary
20 glass mixture to 3-9% and heating the glass under 20
21 atmospheres pressure, the glass has been experimentally
22 flowed at 650°C. This allows glass to be reflowed at a
23 temperature slightly beneath that at which aluminum melts
24 (aluminum melts at about 660°C). Although an aluminum-
25 silicon eutectic melts at 577°C and an aluminum copper
26 eutectic melts at 548°C, the glass of this invention
27 closely approaches these melting points thereby, in some
28 instances, making it possible to reflow glass following
29 the deposition of aluminum interconnects without melting
30 the aluminum interconnects. The glass of this invention
31 is particularly suitable for use with localized glass
32 reflow techniques involving the use of lasers wherein
33 local regions of the glass can be reflowed without signi-
34 ficantly increasing the temperature of adjacent portions
35 of the semiconductor circuit. Thus, even though the
36 melting temperature of the glass is slightly higher than
37 that of aluminum, with careful control of the areas heated
38

1 the melting temperature of this glass is sufficiently low
2 that glass can be locally heated and reflowed without
3 melting adjacent regions of aluminum.
4

5 Although phase diagrams for germanium dioxide/silicon
6 dioxide mixtures are known for bulk systems, these phase
7 diagrams generally do not apply to the thin films commonly
8 employed in the semiconductor industry. As used herein,
9 the term "thin film" is meant to refer to a film of silicon
10 dioxide/germanium dioxide having a thickness generally
11 less than about 5 microns and typically less than about 2
12 microns. The thicknesses of films formed using the tech-
13 niques of this invention for insulation layers in inte-
14 grated circuits can drop as low several hundred angstroms
15 under proper conditions but more typically range in the
16 thousands of angstroms.
17

18 Other embodiments of this invention will be obvious
19 to those skilled in the art in view of the above descrip-
20 tion. The above description is intended only to be
21 exemplary and not limiting.
22

23 I claim:
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1 1. A binary glass film formed of germanium dioxide
2 and silicon dioxide.
3

4 2. The structure of Claim 1 wherein the germanium
5 dioxide is no greater than approximately 50% by weight of
6 the mixture.
7

8 3. The glass of Claim 1 wherein said glass film
9 includes phosphorus.
10

11 4. The structure of Claim 3 wherein said phosphorus
12 comprises 3-9% by weight of the glass film.
13

14 5. Structure as in Claim 4 wherein said phosphorus
15 is in the form of P_2O_5 .
16

17 6. A glass film comprising a mixture of an oxide of
18 germanium and an oxide of silicon possessing a melting
19 temperature beneath approximately 900°C.
20

21 7. The structure of Claim 6 wherein said glass film
22 possesses a melting temperature between approximately
23 650°C to 900°C.
24

25 8. The structure of Claim 7 wherein the melting
26 temperature of said glass film is between approximately
27 700°C and 900°C.
28

29 9. The structure of Claims 1 or 6 wherein the ratio
30 of silicon to germanium in said glass film is such that
31 the resulting glass film is substantially insoluble in
32 water.
33

34 10. The glass film of Claims 1 or 6 wherein the
35 ratio of silicon to germanium by weight in said glass film
36 is such that the resulting glass film is substantially
37
38

1 water insoluble and can be etched using standard oxide
2 etching techniques.
3

4 11. The method of forming a glass film comprising
5 depositing a binary glass comprising a mixture of oxides
6 of germanium and silicon from the vapor deposition of
7 reaction constituents comprising compounds of germanium
8 and silicon.
9

10 12. The method of Claim 11 wherein the method of
11 depositing said binary glass comprises reacting the
12 compounds of germanium and silicon in a chemical vapor
13 deposition reactor at selected temperatures.
14

15 13. The method of Claim 12 wherein the reaction
16 constituents comprise germane and silane.
17

18 14. The method of Claim 13 wherein said germane and
19 silane gases are reacted at temperatures ranging from
20 350°C to 500°C with oxygen in a nitrogen carrier gas.
21

22 15. The method of Claim 14 wherein the germane has a
23 flow rate of approximately 3.67 cc/min, the silane has a
24 flow rate of approximately 7.33 cc/min, and the germane
25 and silane are reacted with oxygen in a nitrogen carrier
26 gas wherein the oxygen has a flow rate of approximately
27 100 cc/min and the nitrogen has a flow rate of approxi-
28 mately 2 liters/min.
29

30 16. The method of Claim 15 wherein the reaction
31 occurs at approximately 450°C.
32

33 17. The product made by the process of Claims 11,
34 12, 13, 14, 15 or 16.
35
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European Patent
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EUROPEAN SEARCH REPORT

Application number

EP 82400446.9

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
X	US - A - 3 669 693 (DALTON) * Column 1, lines 15-18; column 2, lines 4-16, 43-55 *	1,2	C 03 C 3/12 C 23 C 13/04// H 01 L 21/316 H 01 L 21/473
A	US - A - 4 196 232 (SCHNABLE) * Column 2, lines 24-64; column 5, line 62 - column 6, line 15 *	1,3-5, 11,12	H 05 K 1/05 H 05 K 3/28
			TECHNICAL FIELDS SEARCHED (Int.Cl. 3)
			C 03 C C 23 C H 01 B H 01 L H 05 K
			CATEGORY OF CITED DOCUMENTS
			X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: earlier patent document, but published on, or after the filing date D: document cited in the application L: document cited for other reasons
<input checked="" type="checkbox"/> The present search report has been drawn up for all claims			&: member of the same patent family, corresponding document
Place of search VIENNA		Date of completion of the search 07-06-1982	Examiner HAUSWIRTH